Unraveling Phase Transitions in Complex Oxides

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Complex oxides are a class of materials containing a variety of competing strong interactions that create a subtle balance to define the lowest energy state, which leads to a wide variety of interesting properties (e.g. superconductivity, magnetism,...). These states arise from the interaction between the charge, orbital, spin, and lattice degrees of freedom. Within this class of materials one of the most interesting phenomena is the wide class of phase transitions between different ground-states. For example, metal-insulator transitions that are associated with structural changes (e.g. vanadates), magnetic transitions (e.g. manganites), or other state changes. Understanding the transition becomes complex due to two entangled changes (i.e. magnetic and metallicity). While often studied as a function of slowly varying external input (magnetic or electric fields, temperature,…), it is more insightful to study phase transitions through ultrafast perturbation where one can manipulate one part of the system to disentangle the problem.

However, this approach raises an interesting second line of thinking; do phase transitions triggered by different external inputs lead to the same ground-state or one which appears to be the same? Consider the case of of a system which is nominally a charge ordered antiferromagnet ($Pr_{0.7}Ca_{0.3}MnO_3$). Through application of optical, electrical, or magnetic perturbation it can be driven into a metastable ferromagnetic-metallic state at low temperature. Recently we have been working to compare changes in electronic structure probed via soft x-ray spectroscopy when the system is driven into a metastable metallic state either by optical or magnetic field excitation. Here, I will use these results to motivate thoughts one how frontier experiments could be harness to understand phase transitions in complex systems.

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